Study the Impact of Blast Load on G+7 Multistoried RCC Structure with Varied Distances

P.Srinivasa Rao, P.Manoj Kumar, G.Tirupathi Naidu

Abstract— Nowadays, due to increased terrorist activity throughout the world, Blasts have been taking place irrespective of the location. In order to withstand such blasts, the structure should be designed such a way that the detailing and grade of concrete should be improvised. This current study includes the behaviour of G+7 multi storied structure subjected to 100 kg TNT explosion which is assumed to be taken place at 10 m, 20 m, 30 m and 40 m away from the structure. As per IS 4991:1968, Blast Pressures are calculated manually and executed in STAAD Pro tool. The results of Blast loads on structure is compared in its static condition and redesigned the structure to sustain the Blast loads.

Key words: Blast, Tri Nitro Toluene, Blast Pressures, Explosion, STAAD Pro

1. INTRODUCTION

Shock waves are generated as a result of explosion (blast) which moves in all directions outwardly. Shock wave is time dependent and enormous energy was released in a short time. If the shock wave encountered the surface, the pressures rises instantaneously to a peak value. Dependent on explosion peak values are calculated. Meganadh et al., (2017) studied G+5 multi storied rcc structure blast by placing blast at 40 m away from the structure. They conclude by Increase in stiffness of structural members by increasing in size gave better results and also resist uplift forces. Bhosale et al., (2016) done on the subject of Dynamic Behaviour of RCC framed structures subjected to Blast load. It was observed that the maximum acceleration, maximum velocity and nodal displacement decreases as standoff distance increases. Aditya Kumar singh et al.,(2016)studied on the Behaviour of Reinforced concrete beams under different kinds of blast loads and observed non-linear analysis of beams and columns satisfy the stability of the structure. Amol et al., (2013) performed analysis on rcc structure by different explosions with different floor sections and concluded when explosion quantity increases the phase duration decreases. Asha Lakshmi et al., (2015) studied on rcc bridge pier structures by varying standoff distances and explosions and said that by increasing diameter, grade of steel, and spacing of lateral ties increases the stability of the structure. Depending upon the above studies my current study is to find out the behaviour of rcc structure, in front face, side face and rear face with different standoff distances. Behaviour of structure is observed in STAAD Pro tool and finally make structure to sustain blast loads.

1.2 PRELIMINARY DESIGN AND LOAD SPECIFICATIONS

Column size	:	0.3 m x 0.5 m
Beam size	:	0.3 m x 0.4 m
Thickness of Slab	:	150 mm
Dead Load	:	14.3 KN/m^2
Live Load	:	2 KN/m^2
Blast Load	:	By using code book IS 4991: 1968
Combination Load	:	1.5 Dead Load + Live Load
Materials used	:	M 25, Fe 500

As per specifications of IS 4991: 1968, we are not supposed to consider any Wind Load effect of the structure.

3. Methodology

Consider a G+7 multi storied RCC structure subjected to a Blast load with 100 kg TNT, G+7 multi storied structure was drawn in AUTOCAD tool and the same drawing was imported into the STAAD Pro tool. The Blast is considered to be taken place at a distance of 10 m, 20 m, 30 m, and 40 m respectively. The length of the design structure is 38 m (length) in x direction, 14.4 m (width) in z direction, and 24 m (height) in y direction. Each storey height is 3 m. By using two point formula we calculated the target distance. Consider the Blast is taken place at a height of 1.5m from Ground level i.e. at (0, 1.5, 0) at center of the structure and 10m, 20m, 30m and 40m away from the structure. The detailed calculations are given below.

$$(\mathbf{X},\mathbf{Y},\mathbf{Z}) = \sqrt{((\mathbf{X_2}-\mathbf{X_1})^2+(\mathbf{Y_2}-\mathbf{Y_1})^2+(\mathbf{Z_2}-\mathbf{Z_1})^2)} \quad (1)$$

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Figure 1. Plan view in AUTOCAD

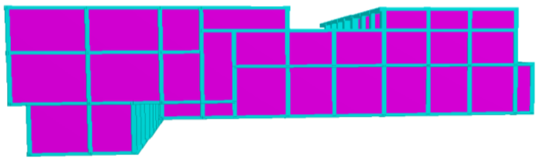

Figure 2.Plan view in STAAD PRO

3.1 Sample Calculation for Scaled distance of 10 m distance

Scaled Distance (SD) = Actual Distance / (Explosion weight in tonnes) $^{1/3}$

$= D/W^{1/3}$ (2)

Table 1 Determination of Scaled distance

X_1	Y_1	Z_1	X_2	Y_2	Z_2	Actual Distance (m)	Scaled Distance (m)
0	1.5	0	10	1.5	0	10	21.54
0	1.5	0	10	4.5	1.8	10.59	22.82
0	1.5	0	10	7.5	3.6	12.2	26.29
0	1.5	0	10	10.5	5.4	14.4	31.23
0	1.5	0	10	13.5	7.2	17.2	37.05
0	1.5	0	10	16.5	9	20.14	43.41
0	1.5	0	10	19.5	10.8	23.25	50.09
0	1.5	0	10	22.5	12.6	26.4	56.99

4. RESULTS AND DISCUSSIONS

By using the Scaled Distance we calculated the different types of pressures like Pro, Pso , tr, to, td, qo,. The pressure decreases with increase in time, so the peak pressures are decreased with respective to time. The formulae for decrement pressures are

$$P_{ro} = P_{so}\left((2+6P_{so}) \div (P+7P_a)\right) \quad (3)$$

$$P_S = P_{so}\left(1-(t \div t_o)e^{-(t/t_o)}\right) \quad (4)$$

$$q = q_o\left(1-(t \div t_o)e^{-(t/t_o)}\right) \quad (5)$$

Where P_a = the ambient atmospheric pressure.

Taking P_a = 1kg/cm^2

P_{ro} =Peak reflected over pressure

P_{so} =Peak side over pressure

q_0 = Peak dynamic pressure

P_s = Side pressure

q= Dynamic pressure

But in this current study we design the structure at peak values only. So by using code book we calculate directly peak values. The Pressures are converted into uniformly distributed load (UDL).

Table 2 Calculation of Different types of Pressures for 10 m scaled distance

X	P_{ro}	P_{so}	q_o	t_o	t_d	t_r	FF	RF	SF
43.08	185.8	72.4	17.0	14.0	9.5	0	1458	216	216
43.74	179.1	70.2	16.0	14.2	9.5	5.7	1219.8		196.6
45.64	161.8	64.5	13.6	14.6	9.9	12.8	750.67		151.6
48.66	142.1	57.7	11.0	15.0	10.6	21.6	441.64		110.8
52.58	120.7	50.4	8.46	15.7	11.2	31.2	287		69.7
57.24	100.3	42.7	6.1	16.5	12.2	41.5	198.96		64.6
62.46	86.4	37.5	4.7	17.2	12.8	52.3	143.42		50.8
68.12	73.5	32.6	3.6	17.9	13.5	62.6	107.42		40.5

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Table 3 Calculation of Different types of Pressures for 30m scaled distance

X	P_{ro}	P_{so}	q_o	t_o	t_d	t_r	FF	RF	SF
43.08	185.8	72.4	17	14.0	9.5	0	202.8	65.5	65.5
43.74	179.1	70.2	16	14.2	9.5	8.29	195.1	63.8	63.8
45.64	161.8	64.5	13.6	14.6	9.9	16.8	175.1		59.0
48.66	142.1	57.7	11.6	15.0	10.6	25.7	153.1		53.3
52.58	120.7	50.4	8.4	15.7	11.2	35.1	129.1		47.0
57.24	100.3	42.7	6.1	16.5	12.2	45.1	106.4		40.3
62.46	86.4	37.5	4.7	17.2	12.8	54.6	91.2		35.6
68.12	73.5	32.6	3.6	17.9	13.5	64.8	77.1		31.1

Table 4 Calculation of Different types of Pressures for 30 m scaled distance

X	P_{ro}	P_{so}	q_o	t_o	t_d	t_r	FF	RF	SF
64.63	80.6	35.3	4.2	17.4	13.1	0	84.8	33.6	33.6
65.07	79.4	34.9	4.1	17.5	13.2	9.15	83.5	33.2	33.2
66.36	76.4	33.7	3.8	17.7	13.3	18.9	80.2		32.2
68.47	72.8	32.3	3.5	17.9	13.5	27.7	76.4		30.9
71.31	68.1	30.4	3.1	18.2	13.7	37.3	71.3		29.1
74.81	62.3	27.1	2.7	18.6	14.2	47.1	65.0		26.1
78.88	55.9	25.7	2.2	19.0	14.7	57.0	58.2		24.7
83.43	53.3	24.1	2.0	19.5	14.8	67.2	55.4		23.3

Table 5 Calculation of Different types of Pressures for 40 m scaled distance

X	P_{ro}	P_{so}	q_o	t_o	t_d	t_r	FF	RF	SF
86.17	50.8	23.2	1.8	19.8	14.9	0	84.8	33.6	33.6

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86.5	50.	23.1	1.8	19.8	14.9	9.15	83.5	33.2	33.2
87.48	49.5	22.8	1.7	19.9	15.0	18.3	80.2		30.9
89.09	47.9	22.3	1.6	20.2	15.3	27.7	76.4		29.1
91.29	45.2	21.1	1.5	20.3	15.7	37.3	71.3		26.1
94.05	42.3	19.6	1.3	20.7	16.2	47.1	65.0		24.7

where

FF = Front Face Pressure in kN/m^2

RF = Rear Face Pressure in kN/m^2

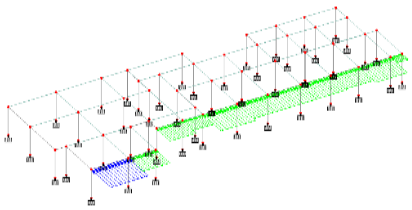
SF = Side Face Pressure in kN/m^2

to = Positive Phase Duration in milli seconds

td = Duration of Equivalent Triangular Pulse in milli seconds

tr = Reflected Time in milli seconds.

The below figures are application of Pressure in different faces at Ground Floor level and this application procedure is same to all stories.



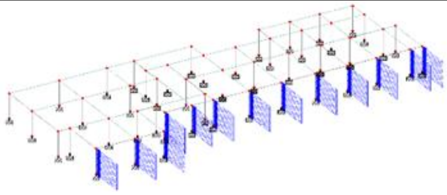


Figure 3. Application of Pressure in Front Face at Beam and Front Face at Columns

NOTE: Application of Pressure in Rear face and Side face of Columns and Beams same as above figure(Figure 3).

5. REVISED DESIGN SPECIFICATIONS OF MEMBERS

After application of pressures we need to change cross sectional parameters to sustain the Blast load

Table 6 Variation of Beam Cross sections with Storey height

Storey	Beam size (m)			
	10 m	20m	30 m	40 m
Ground floor (G)	1 x 1.5	0.6 x 0.65	0.4 x 0.5	0.4 x 0.5
G+1	1 x 1.5	0.6 x 0.55	0.4 x 0.5	0.4 x 0.5
G+2	1x1.5	0.6 x 0.55	0.3 x 0.4	0.4 x 0.5
G+3	0.90x0.95	0.6 x 0.55	0.3 x 0.4	0.4 x 0.5
G+4	0.65x0.75	0.6 x 0.55	0.3 x 0.4	0.4 x 0.5
G+5	0.55x0.65	0.3 x 0.45	0.3 x 0.4	0.4 x 0.5
G+6	0.50x0.60	0.3 x 0.45	0.3 x 0.4	0.4 x 0.5
G+7	0.50x0.60	0.3 x 0.45	0.3 x 0.4	0.4 x 0.5

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Table 7 Variation of Column Cross sections with Storey height

Storey	Column Size (m)			
	10 m	20 m	30 m	40 m
Ground floor (G)	1.5 x 2	0.5 x 0.6	0.35 x 0.55	0.4 x 0.55
G+1	1.5 x 2	0.5 x 0.6	0.35 x 0.55	0.4 x 0.55
G+2	1.5 x 2	0.5 x 0.6	0.35 x 0.55	0.4 x 0.55
G+3	0.95 x 1	0.5 x 0.6	0.35 x 0.55	0.4 x 0.55
G+4	0.70 x 0.80	0.5 x 0.6	0.35 x 0.55	0.4 x 0.55
G+5	0.65 x 0.70	0.4 x 0.5	0.3 x 0.4	0.4 x 0.55
G+6	0.65 x 0.70	0.4 x 0.5	0.3 x 0.4	0.4 x 0.55
G+7	0.65 x 0.70	0.4 x 0.5	0.3 x 0.4	0.4 x 0.55

6. DEFLECTION VALUES

The maximum permissible deflections in any framed structure is restricted to H/500.Where H is the Height of the individual storey.

Table 8 Deflection values with increasing Storey height

Storey	Deflection (mm)			
	10 m	20 m	30 m	40 m
Ground Floor(G)	0.115	0.651	0.944	0.861
G+1	0.207	1.212	1.763	1.608
G+2	0.275	1.694	2.476	2.255
G+3	0.426	2.096	3.096	2.803
G+4	0.616	2.413	3.613	3.251
G+5	0.8	2.778	4.130	3.598
G+6	0.94	3.039	4.492	3.835
G+7	1.003	3.152	4.652	3.939

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7. COMBINED GRAPHS OF PRESSURE VS STOREY AND DEFLECTION VS STOREY

The below graphs shows the variation of pressures of 10m, 20m, 30m, and 40 m with storey height.

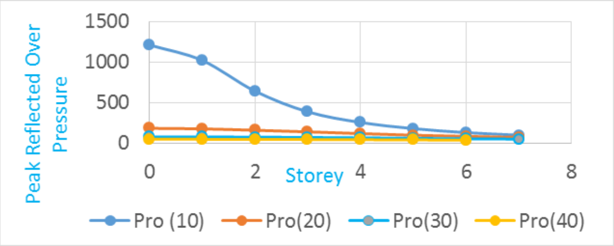

Figure 4. Peak Reflected Over Pressure vs Storey

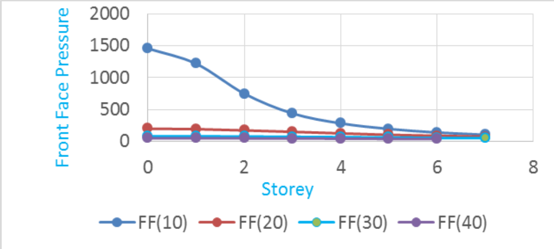

Figure 4. Front face Pressure vs Storey

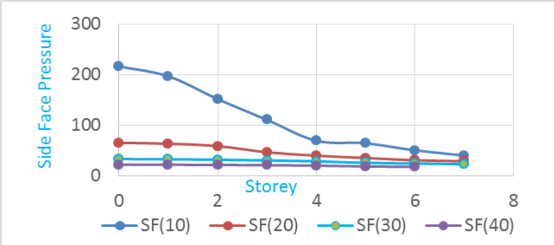

Figure 5. Side Face Pressure vs Storey

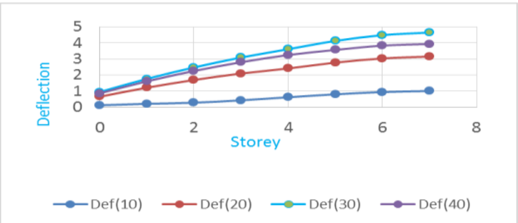

Figure 6 Deflection vs Storey

8. CONCLUSIONS

From the above results we can conclude that

1. Front face pressure depends on Peak reflected pressure. If Peak reflected pressure increases the Front face pressure also increases and we also observed that front face pressure impact is more than the side face pressure and Rear face pressures.
2. Failure of the members of the structure is mainly due to Front face pressure at ground floor level and this pressure decreases with increasing storey height.
3. Side face pressure depends on Peak side over pressure. If Peak side over pressure increases Side face pressure also increases.
4. Rear face pressure depends on transit time if transit time is less than the positive phase time then only we consider Rear face pressure. In this study we consider Rear face pressure, one floor (ground floor) for 10 m distance and two floors (ground and first floor) for 20, 30 and 40 distance.
5. Peak reflected pressure, Peak side over pressure, Front face pressure, Side face pressures are inversely proportional to scaled distance.
6. Shock Velocities are decreases with increasing scaled distance. The velocity is more at 10 m distance.
7. In this study we observed that column members are mainly effected by the pressures compared to beams and slabs. So, we designed columns with more sectional parameters. Compared to conventional design these cross sections are very large but to sustain the enormous amount of pressure this much cross section properties must be required.
8. All the deflections are with in maximum permissible limits.
9. Deflections are decreases with increasing of column sections.
10. Deflections are increases with increasing of Scaled Distance. But in 40 m distance the deflection decreases compared to 30 m distance because the cross sectional dimensions are small compared to the previous one.

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